PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
11171-4PCT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/CA 98/ 00921	29/09/1998	
Applicant		
MODEX-LITE INC. et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 2 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1

[X] as suggested by the applicant.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

[ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 98/00921

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01F29/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 006, no. 222 (E-140), 6 November 1982 & JP 57 126110 A (TOKYO DENKI KAGAKU KOGYO KK), 5 August 1982 see abstract ---	1
X	GB 2 075 755 A (TANAKA OSAMU) 18 November 1981 see figures 4E,9B ---	7-9
A	US 2 869 050 A (NORTH AMERICAN PHILIPS COMPANY) 13 January 1959 see figure 7 --- -/--	16,20

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 May 1999	31/05/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Vanhulle, R

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 98/00921

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 097, no. 006, 30 June 1997 & JP 09 035958 A (ZENSHIN DENRYOKU ENG:KK), 7 February 1997 see abstract	20
A	GB 2 259 190 A (IBM) 3 March 1993 see figure 8	20
A	WO 94 01814 A (DELAIN ROBERT) 20 January 1994 see figure 4	21,22
A	GB 1 424 986 A (RIVAS R V DE) 11 February 1976 see page 1, line 88 - page 3, line 80	21,22
A	FR 2 472 824 A (TRAN VAN SACH) 3 July 1981	
A	US 3 403 323 A (WANLASS LESLIE KENT) 24 September 1968	

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 98/00921

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 2075755 A	18-11-1981	NONE	
US 2869050 A	13-01-1959	NONE	
GB 2259190 A	03-03-1993	CA 2074892 A	03-03-1993
		CN 1073037 A,B	09-06-1993
		JP 5249911 A	28-09-1993
		KR 9607266 B	29-05-1996
		US 5350980 A	27-09-1994
WO 9401814 A	20-01-1994	AU 4666693 A	31-01-1994
GB 1424986 A	11-02-1976	NONE	
FR 2472824 A	03-07-1981	NONE	
US 3403323 A	24-09-1968	FR 1481300 A	14-08-1967

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

Date of mailing (day/month/year) 22 May 2000 (22.05.00)	
International application No. PCT/CA98/00921	**Applicant's or agent's file reference** 11171-4PCT
International filing date (day/month/year) 29 September 1998 (29.09.98)	**Priority date** (day/month/year)
Applicant PIASKOWSKI, Andrew, D. et al	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   31 March 2000 (31.03.00)

   [ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer F. Baechler
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

09/806067

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

15

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
11171-4PCT		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/CA98/00921	29/09/1998	29/09/1998 Δ
International Patent Classification (IPC) or national classification and IPC H01F29/14		
Applicant MODEX-LITE INC. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of (5) sheets.

14

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
31/03/2000	23.02.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Van den Berg, G Telephone No. +49 89 2399 2499

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/CA98/00921

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:
Description, pages:

1,4,6,8,9,12,13	as originally filed			
2,3,3a,5,7,7a,10, 11,11a	as received on	25/10/2000	with letter of	17/10/2000

Claims, No.:

1-12,13 (part), 18-20	as received on	25/10/2000	with letter of	17/10/2000
13 (part),14-17	as received on	26/10/2000	with letter of	19/10/2000

Drawings, sheets:

1/11-11/11	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence

listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☐ the claims, Nos.:

   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1 - 20
	No:	Claims	none
Inventive step (IS)	Yes:	Claims	1 - 20
	No:	Claims	none
Industrial applicability (IA)	Yes:	Claims	1 - 20
	No:	Claims	none

2. Citations and explanations
   see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

To point V:

Patent Abstracts of Japan, vol. 006, no. 222 (E-140), 6 November 1982 & JP 57 126110 A describes an inductance element wherein a magnetic core oppositely contacts with a central magnetic leg and side magnetic legs of the magnetic core with these magnets through a permanent magnet in the element used for a switching regulator. A coil is wound around the central leg.
GB 2075755 relates to a rod-shaped or C-shaped magnet amplifier element which consists of a magnetic material which has a diamagnetic material of a particular thickness interposed into a portion of the magnetic material. Furthermore, an antenna using a toroidal magnetic amplifier element and a coil wound on the magnet element wherein ends of the element portions are separated by a diamagnetic material
US 2869050 A discloses permanent-magnet biased, closed, magnetic circuits wherein a permanent magnet with predetermined magnetisation is mounted in series with a highly-permeable core member to form a closed magnetic circuit containing at least one winding.
Patent Abstracts of Japan, GB 2 259 190 A, WO 94 01814 A, GB 1 424 986 A, FR 2 472 824 A and US 3 403 323 A do not relate to a permanent core device as claimed in claims 1 and 7 nor to a multiphase electrical device using such permanent core devices as claimed in claim 14.

1. (Novelty)
   Consequently, the subject-matter of claims 1, 7 and 14 meets the requirement of Article 33(2) PCT.

2. (Inventive step)
   The subject-matter of claims 1, 7 and 14 is not rendered obvious by the cited prior art because none of the documents mentioned above suggests to place a permanent magnet in a gap of a ferromagnetic core structure wherein the coil is so positioned that the fields produced by the coil(s) are additive.
   The dependent claims define advantageous embodiments of this subject-matter.
   Therefore, the subject-matter of claim 1 - 20 meets the requirement of Article 33(3) PCT.

3. (Industrial applicability) The subject-matter of claims 1 - 20 meets the requirement

of Article 33(4) PCT.

To point VIII:

Observations under Article 6 PCT:

1. The claims are not supported by the description (cf. pages 2, 3).

2. The wording of claim 1 and 7 is not consistent with respect to "magnetic conductive material (2)" and "ferromagnetic" piece 6 instead of using "ferromagnetic" consistently. This also applies to the core structure in claim 14.

3. Claim 14 does not express that first and second structure and permanent magnets form an integral unit. The wording "magnet sets" is not clear. The wording "said first and second frames" in claim 14 has no antecedent in the preceding wording of the claim.

In addition, magnetic devices such as transformers, chokes and inductors commonly used silicon grade steel for the magnetic core and copper or aluminum for the windings. Over the last decades, this technology has not progressed but improvements have been made in materials and processes for the constructions of such transformers. However, a need still remains for magnetic technology with reduced energy loss characteristics, reduced weight and lower cost. A need also exists for energy efficient and cost efficient transformers which can be utilized in high power consumption circuits, such as ballasts for street lighting and arc discharge lamp applications, or circuits used in current, power control and distribution.

SUMMARY OF THE INVENTION

It is a feature of the present invention to provide inductor devices which are highly energy efficient and produce low amounts of heat.

It is another feature of the present invention to provide inductor devices which are lightweight and compact.

It is a further feature of the present invention to provide an inductor device which can be used in a variety of different applications, such as a transformer, current controller, or as a power equipment protection device.

According to the above features, from a first broad aspect, the invention provides a permanent magnetic core device for use as a transformer, inductor, choke, or a component in a current limiting circuit, CHARACTERIZED BY:

first and second layers of magnetic conductive material (2) retained in a predetermined, spaced apart relationship with respect to one another, so as to define opposed facing surfaces at least at first and second end portions thereof, a gap defined between said layers;

a first permanent magnetic piece (3) located at said first end portion between said first and second layers of ferromagnetic material, and a second permanent magnetic piece (3) located at a second end portion between said first and second layers of magnetic conductive material, the first and second permanent magnetic pieces being placed so that their fields are additive;

coil means surrounding each of said first and second layers of magnetic conductive material, said coil means extending within said gap between said first and second permanent magnetic pieces and being placed so that fields produced by the coil means are additive.

In accordance with a second broad aspect, the invention provides a toroidal permanent magnetic core for use as a transformer, choke or component in a current limiting circuit, C H A R A C T E R I Z E D BY:

a first semi-circular toroidal ferromagnetic piece (6) having first and second ends;

a second semi-circular toroidal ferromagnetic piece (6) having first and second ends;

said first and second ends of said first toroidal ferromagnetic piece being arranged to face the first and second ends of said second toroidal ferromagnetic piece, such that the ends of said first and second toroidal pieces are opposed and spaced apart;

permanent magnetic means (7) interposed between said ends of said toroidal ferromagnetic pieces and joined with said toroidal ferromagnetic pieces;

a coil (9) surrounding a portion of said first toroidal ferromagnetic piece or said second toroidal ferromagnetic piece, said first and second toroidal ferromagnetic pieces and said permanent magnetic pieces defining a closed toroidal structure.

In accordance with a third broad aspect, the invention provides a multi-phase electrical device for use as a power distribution transformer, a power distribution protection device or a current limiting device, CHARACTERIZED BY:

a first core structure (21) and a second core structure (24), each of said first core structure and second core structure having a perimeter and at least one vertical limb extending within said perimeter of each core structure;

said first and second core structures being retained in juxtaposition by permanent magnet sets (19, 20) interposed between said first and second core structures; and

coils (18, 22, 23) surrounding at least a portion of said perimeter, and surrounding at least a portion of said at least one vertical limb;

wherein said first and second frames and permanent magnet sets form a unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments of the present invention will now be described with reference to the accompanying drawings in which

FIG. 1 illustrates a perspective view of the preferred magnetic core device of the present invention.

FIG. 12 illustrates a hysteresis curve plotting magnetic flux density versus field strength and which further illustrates the static and dynamic operating points of a flux saturated magnetic core device 16 of Fig. 8.

FIG. 13 illustrates an effective hysteresis curve plotting magnetic flux density versus field strength for the combined operation of the two flux saturated magnetic core devices in Fig. 8.

FIG. 14 illustrates hysteresis curves plotting magnetic flux density versus field strength for a standard inductor, choke or transformer, wherein the magnetic core device of the present invention is operated at non-flux saturated conditions.

FIG. 15 illustrates an application of a three-phase transformer in which the operating conditions of Fig. 14 are applicable.

FIG. 16 illustrates a vector diagram for showing flux vectors that would be established for an embodiment having reduced hysteresis losses.

FIG. 17 illustrates an alternate embodiment of the invention which utilizes the principles illustrated in Fig. 16.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a perspective view of a preferred embodiment of the permanent magnetic core device of the present invention. This device includes two coils 4,5 wrapped around layers of magnetically-conductive steel material 2, forming a ferromagnetic core. Permanent magnetic pieces 3 are placed at opposing ends of the assembly. However, it may be desirable in certain applications to utilize only one magnet in the magnetic core device. To couple the magnetic pieces 3 to the ferromagnetic layers 2, magnetic pole pieces 1 may be utilized in layers positioned between the magnetic pieces 3 and the ferromagnetic layers 2. The coils are _____

Figure 2, "μo" is the permeability of free space and "μr" is the permeability of the ferromagnetic core layers 2.

If a field is applied opposing the magnets by the coils 4 and 5 of Figure 1 of turns N, and current 1, then the residual flux density in the magnets will be given by:

(2) $$Br = \frac{(Npls \cdot Hm \cdot th - N \cdot I) \cdot \mu o}{\left(\frac{H \cdot Lm}{\mu r \cdot Wi}\right) + Npls \cdot th}$$

Since the flux density in the ferromagnetic core is related to the magnetic residual flux density "Br" by the ratio Lm/W, the ferromagnetic core saturation flux density can be approximated by:

(3) $$Bs = \frac{(Npls \cdot Hm \cdot th - N \cdot I) \cdot \mu o}{\left(\frac{H \cdot Lm}{\mu r \cdot Wi}\right) + Npls \cdot th} \cdot \left(\frac{Lm}{Wi}\right)$$

If the value "Bs" is greater than the value required to saturate the core Bsat, then the inductance of the permanent magnetic core assembly will be minimal, as the current I in coils 4, 5 of Figure 1 is increased to the point where the core desaturates, then the inductance of the permanent magnetic core will maximize. Thus, equation (3) demonstrates that for the saturation mode of the permanent magnetic core device, this device operates as a controller of current. In AC circuits, the maximum inductance value will form a high impedance to current, while the minimal inductance will form a low impedance to current.

Characteristics of Permanent Magnetic Core Device

Figure 5 illustrates the variations of inductance against current on the device of Figure 1 in the magnetic flux saturated condition. As the current

changes from the negative to the positive direction, the inductance suddenly increases to a constant, steady level. With this sudden change in inductance, the impedance to _____

technology of the preferred embodiment from Figure 1 (or later described alternate embodiment of Figures 3, 4 and 15) produces energy losses that are much lower than the energy losses experienced by conventional magnetic devices. Such reductions in energy losses translate in a reduction of heat and lower operating costs when the permanent magnetic core devices are utilized in a circuit.

ALTERNATE EMBODIMENTS OF THE INVENTION

Figures 3 and 4 illustrate the alternative embodiments for the permanent magnetic core device. In Figure 3, the permanent magnets 7 are aligned in a plane. Surrounding the magnets are a toroidal ferromagnetic core 6 and pole pieces 8 attached to the internal and external peripheries of the ferromagnetic core 6. A coil 9 is wrapped around the ferromagnetic core 6. Figure 4 illustrates a similar device, although this embodiment does not utilize the pole pieces, and the permanent magnets are shown at 10. In this embodiment, the permanent magnets 10 are shown in parallel planes, which are at an angle to the diametric plane of the toroid. In a further alternate embodiment (not shown) the arrangement of Figure 4 is utilized, but the permanent magnets 10 are arranged in non-parallel planes.

The embodiments of Figures 3 and 4 have been found to be ideal for use as chokes, although their application in specific circuits are not limited to chokes alone. For example, the devices of Figures 3 and 4 may not be utilized as inductors or controllers of current, or transformers.

Another alternate embodiment of the invention is presented in Figure 15. Two core structures 21 and 24 are placed adjacent to one another. Magnetic assemblies are composed of magnet sets 19, 20 and pole pieces 25, and these assemblies are then sandwiched between the two core structures 21

and 24. Each of the six magnetic assemblies are arranged to have opposite polarity to each adjacent magnetic assembly in both horizontal and vertical directions. However, magnetic polarity may be varied according to a given application. Each of the three vertical limbs are enclosed by coils 18, 22, 23, respectively. This particular device is advantageous when used as a power distribution transformer, a power distribution protection device or a current limiting device. The basic theory behind this device has been described according to Figures 5, 6, 7, 11, 12, 13 and 14. An additional discovery has been made in which we have found that if the magnetic field is established in the core which is perpendicular to the magnetic field of the permanent magnets, then the hysteresis curve for such a device will also define a smaller area than what would be observed if the perpendicular magnetic field did not exist. Thus, the creation of a magnetic field in the core which is perpendicular to the field created by horizontal pairs of permanent magnets will result in a device with substantially reduced heat generation, and greater energy efficiency. The transformer device of Figure 15 may be used in three-phase applications and displays the characteristic shown in Figure 6.

As we described the usefulness of static magnetic biasing in reducing core losses in ferromagnetic materials, we have also set out the principle that the bias field may not be restricted to the conventional direction of flux flow, but may also be used in the "orthogonal direction". Our invention can be extended to AC orthogonal biasing in which further advantages are realized in the application of power transformers.

The advantages of magnetic biasing for reducing hysteresis losses have been demonstrated in FIGS. 11, 12, 13 and 14, however, we have found that many ferromagnetic materials, including ferrites, can be biased in a multi-dimensional manner as demonstrated in Figure 16. Figure 16 illustrates a

portion of a ferromagnetic material in which several flux density vectors are imposed. The material will exhibit a maximum flux density vector in the normal direction depicted by the non-linear vector B_norm. Another non-linear flux density vector B_orth may be imposed by a magnet or by a coil, resulting in an overall non-linear flux density vector B_res_O. Although the material may have a magnetic _____

CLAIMS:

1. A permanent magnetic core device for use as a transformer, inductor, choke, or a component in a current limiting circuit, CHARACTERIZED BY:

first and second layers of magnetic conductive material (2) retained in a predetermined, spaced apart relationship with respect to one another, so as to define opposed facing surfaces, at least at first and second end portions thereof, and a gap between said layers;

a first permanent magnetic piece (3) located at said first end portion between said first and second layers of ferromagnetic material, and a second permanent magnetic piece (3) located at a second end portion between said first and second layers of magnetic conductive material, the first and second permanent magnetic pieces being placed so that their fields are additive;

coil means surrounding each of said first and second layers of magnetic conductive material, said coil means extending within said gap between said first and second permanent magnetic pieces and being placed so that fields produced by the coil means are additive.

2. The permanent magnetic core device as claimed in claim 1, wherein said coil means comprises one or more coils.

3. The permanent magnetic core device as claimed in claim 2, wherein each of said one or more coils are wrapped around said respective first and second layers of core material.

4. The permanent magnetic core device as claimed in claim 1, wherein said first and second permanent magnetic pieces (3) are supported by

magnetic pole pieces (1) located between the first and second layers of magnetic conductive material (2) and the respective first and second permanent magnetic pieces.

5. A toroidal permanent magnetic core for use as a transformer, choke or component in a current limiting circuit, C H A R A C T E R I Z E D BY:

a first semi-circular toroidal ferromagnetic piece (6) having first and second ends;

a second semi-circular toroidal ferromagnetic piece (6) having first and second ends;

said first and second ends of said first toroidal ferromagnetic piece being arranged to face the first and second ends of said second toroidal ferromagnetic piece, such that the ends of said first and second toroidal ferromagnetic pieces are opposed and spaced apart;

permanent magnetic means (7) interposed between said ends of said toroidal ferromagnetic pieces and joined with said toroidal ferromagnetic pieces;

a coil (9) surrounding a portion of said first toroidal ferromagnetic piece or said second toroidal ferromagnetic piece, said first and second toroidal ferromagnetic pieces and said permanent magnetic pieces defining a closed toroidal structure.

6. The toroidal permanent magnetic core as claimed in claim 5, wherein said permanent magnetic means (7) comprises two spaced-apart permanent magnets.

7. The toroidal permanent magnetic core as claimed in claim 6, wherein said spaced-apart permanent magnets (7) are arranged along a single plane.

8. The toroidal permanent magnetic core as claimed in claim 6, wherein said spaced apart permanent magnets (7) are arranged along parallel planes, and angled with respect to a diametric plane of said toroidal permanent magnetic core.

9. The toroidal permanent magnetic core as claimed in claim 6, wherein said spaced apart permanent magnets (7) are arranged along non-parallel planes.

10. The toroidal permanent magnetic core as claimed in claim 5, further including at least one pole piece (8) attached to a periphery of said first and second toroidal ferromagnetic pieces (6).

11. The toroidal permanent magnetic core as claimed in claim 5, further including a plurality of pole pieces (8) attached to a periphery of said first and second toroidal ferromagnetic pieces (6).

12. The toroidal permanent magnetic core as claimed in claim 11, wherein said toroidal permanent magnetic core includes an inner periphery and an outer periphery and said plurality of pole pieces are attached to said internal periphery and said outer periphery.

13. The toroidal permanent magnetic core as claimed in claim 5, wherein said toroidal permanent magnetic core includes an inner and outer

periphery and said coil (9) is wrapped around portions of said inner and outer peripheries.

14. A multi-phase electrical device for use as a power distribution transformer, a power distribution protection device or a current limiting device, CHARACTERIZED BY:

a first core structure (21) and a second core structure (24), each of said first core structure and second core structure having a perimeter and at least one vertical limb extending within said perimeter of each core structure;

said first and second core structures being retained in juxtaposition by permanent magnet sets (19, 20) interposed between said first and second core structures; and

coils (18, 22, 23) surrounding at least a portion of said perimeter, and surrounding at least a portion of said at least one vertical limb;

wherein said first and second frames and permanent magnet sets form a unit.

15. The multi-phase electrical device as claimed in claim 14, wherein said magnet sets (19, 20) are sandwiched between said first and second core structures (21, 24).

16. The multi-phase electrical device as claimed in claim 14, wherein said magnet sets (19, 20) comprise a plurality of permanent magnet assemblies positioned adjacent said perimeter.

17. The multi-phase electrical device as claimed in claim 16, wherein each magnet assembly is arranged to have an opposite polarity to other adjacent magnet assemblies.

18. A permanent magnetic core device as claimed in claim 1, wherein a first permanent magnetic core device and a second permanent magnetic core device are joined in series so that a polarity of the first permanent magnetic core device is opposite to a polarity of the second permanent magnetic core device to control alternating current (AC).

19. The multi-phase electrical device as claimed in claim 14, wherein a first magnetic field established by the coils (18, 22, 23) is orthogonal to a second field established by the permanent magnet sets (19, 20), whereby energy losses and hysteresis losses in said multi-phase electrical device are reduced.

20. The multi-phase electrical device as claimed in claim 19, wherein vectored fluxes produced by said orthogonally arranged coils (18, 22, 23) produce a net flux density that exceeds a predetermined saturation flux density of the permanent magnet sets (19, 20).

PATENT COOPERATION TREATY

From the:
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

MITCHELL, R.
SWABEY OGILVY RENAULT
1981 McGill College Avenue
Suite 1600
Montréal, Québec H3A 2Y3
CANADA

PCT

WRITTEN OPINION

(PCT Rule 66)

Date of mailing *(day/month/year)*	17.07.00
Applicant's or agent's file reference	REPLY DUE: **within 3 month(s)** from the above date of mailing
11171-4PCT	

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/CA98/00921	29/09/1998	29/09/1998

International Patent Classification (IPC) or both national classification and IPC

H01F29/14

Applicant

MODEX-LITE INC. et al.

1. This written opinion is the **first** drawn up by this International Preliminary Examining Authority.

2. This opinion contains indications relating to the following items:

I	☒	Basis of the opinion
II	☐	Priority
III	☒	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	☐	Lack of unity of invention
V	☒	Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	☐	Certain document cited
VII	☐	Certain defects in the international application
VIII	☒	Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also: For an additional opportunity to submit amendments, see Rule 66.4.
For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 bis.
For an informal communication with the examiner, see Rule 66.6.

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 29/01/2001.

Name and mailing address of the international preliminary examining authority:

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Authorized officer / Examiner
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I. Basis of the opinion

1. This opinion has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed".*):

Description, pages:

1-13 as originally filed

Claims, No.:

1-22 as originally filed

Drawings, sheets:

1/11-11/11 as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. This opinion has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been and will not be examined in respect of:

☐ the entire international application,

☒ claims Nos. 21, 22.

because:

☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 21, 22 are so unclear that no meaningful opinion could be formed (*specify*):

see separate sheet

☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

☐ no international search report has been established for the said claims Nos. .

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1 - 20: yes
Inventive step (IS)	Claims	1 - 20 : yes
Industrial applicability (IA)	Claims	1 - 20 : yes

2. Citations and explanations

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

To point III:

See comment under VIII.5 please.

To point VIII:

The claims do not meet the requirement of Article 6 PCT:

1. In claim 1 (line 8), the expression "**said** layers of ferromagnetic material" is used yet without appearance of such layers in the preceding wording of claim 1. This observation also applies to the wording "said respective first and second layers of core material" in claim 3.
It further seems that the requirement that the permanent magnetic pieces and the coils are placed in such a manner that their fields are additive is an essential feature of the magnetic core device in the underlying application (cf. description, page 5, lines 27, 28; page 6, lines 2, 3; page 11, lines 14 - 19). These features, at present in claims 5 and 6, should be transferred to claim 1.
Furthermore, the wording of claims 1 - 6 is not consistent with that of the description regarding the expression "inductor device"(claims) and "(permanent) magnetic core device" (description).

2. The last observation under point VIII.1 above also applies to claims 7 - 15 with respect to "toroidal inductor device" and "permanent magnetic core device", respectively.

3. Claim 16 should be directed to a multi-phase magnetic core transformer assembly (cf. figure 15 and corresponding text). The expression "frame" in claim 16 does not seem to appear in the description (cf. page 10, lines 22 - 27). In claim 16, specification of the materials involved is lacking.
It seems that the content of claim 17 is redundant in view of the wording of claim 16 ("said first and second frame being retained in juxtaposition with permanent magnetic means interposed between sad first and second juxtaposed frames").

4. Claims 20 should refer back to permanent magnetic core devices as claimed in

claim 1 (cf. description, e.g. page 8, lines 3 - 5).

5. Claims 21 and 22 are not clear. These claims (see also figures 16 and 17 and corresponding text) seem to relate rather to a method of tuning the operating flux density of an arbitrary magnetic device than to magnetic core devices and assemblies of the preceding claims 1 - 20. Claims 21 and 22 should therefore be either deleted or reformulated to include a link to the devices of the foregoing claims. However, it is noted that in the latter case the application may fail to provide a proper basis for such reformulation.

6. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

To point V:

In expectation of clarified claims, a preliminary evaluation under Article 33(2) - 33(4) PCT reveals the following observations:

1. No statement as to novelty, inventive step and industrial applicability is made with respect to the subject-matter of claims 21 and 22 (cf. points III and VIII. 5)

2. (Novelty)
Insofar as claims 1 - 20 can be understood (cf. point VIII above), the subject-matter thereof does not seem to anticipated by the disclosure of any of the documents cited in the international search report. In particular, GB 2 075 755 A describes a magnetic amplifier element which consists of a permanent magnetic material which has a diamagnetic material of a particular thickness interposed into a portion of the magnetic material.
Consequently, it seems that the subject-matter of clarified claims 1 - 20 would meet the requirement of Article 33(2) PCT.

3. (Inventive step)
Insofar as claims 1 - 20 can be understood (cf. point VIII above), the subject-matter thereof seems to involve an inventive step because none of the documents

nor a combination of their teachings reveals a magnetic core device according to the subject-matter of the independent claims. These claims would therefore meet the requirement of Article 33(3) PCT.
The dependent claims (save claim 17, see point VIII.3) relate to embodiments of the devices claimed in the independent claims and would therefore also meet the requirement of Article 33(3) PCT.

3. (Industrial applicability)
Insofar as claims 1 - 20 can be understood, the subject-matter thereof meets the requirement of Article 33(4) PCT.

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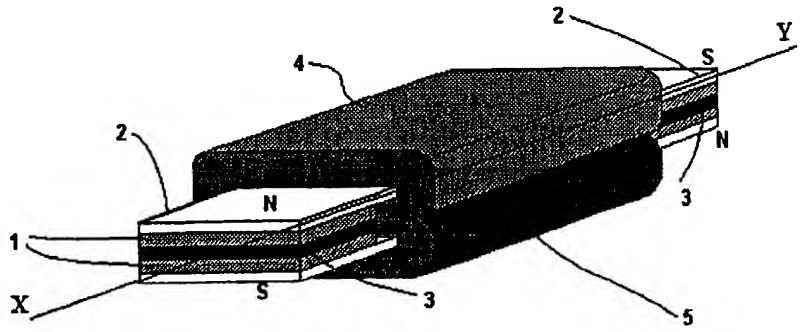
With international search report.

(54) Title: PERMANENT MAGNETIC CORE DEVICE

ORTHOGONAL CONTRUCTION OF MAGNECORE ASSEMBLY



(57) Abstract

Biased core devices and method of use are disclosed in which magnetic core energy losses due to hysteresis and eddy currents are greatly reduced in comparison to the core losses in prior art transformers and inductive devices. The present invention sets forth a transformer or choke device in which permanent magnets are surrounded by electrical steel materials and may be held in place by pole pieces. The magnetic core transformer structure also permits a method of use in which current passing through the device is controlled by the field strength of the permanent magnets. In addition, the biased magnetic core transformer operation may be linear or non–linear, and placed in series or parallel within a circuit. The magnetic components disclosed in the present invention affords both energy loss reductions and size reductions in comparison to known prior art transformers. The invention has many applications, including, but not limited to, the protection of switch gear, current limiting, voltage transformation in power distribution and for current control in arc discharge lamp circuits.

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CLAIMS:

1. An inductor device, comprising:

a magnetic circuit having first and second layers of magnetic conductive material, said layers being retained in a predetermined, spaced apart relationship with respect to one another, so as to define opposed facing surfaces at least at first and second end portions thereof, and a gap defined between said layers;

a first permanent magnetic piece located at said first end portion between said layers of ferromagnetic material, and a second permanent magnetic piece located at a second end portion between said layers of ferromagnetic material;

coil means surrounding each of said first and second layers of ferromagnetic material, said coil means extending within said gap between said first and second permanent magnetic pieces.

2. The inductor device as claimed in claim 1, wherein said coil means comprises one or more coils.

3. The inductor device as claimed in claim 2, wherein each of said one or more coils are wrapped around said respective first and second layers of core material.

4. The inductor device as defined in claim 1, wherein said permanent magnets are supported by magnetic pole pieces located between said first and second layers of ferromagnetic material.

5. The inductor device of claim 1, wherein said magnetic field associated with said first magnetic piece is additive to a magnetic field associated with said second magnetic piece.

6. The inductor device as claimed in claim 2, wherein a magnetic field associated with one of said individual coils is additive to the magnetic field of the other of said coils.

7. A toroidal inductor device, comprising:

a first semi-circular toroidal ferromagnetic piece having first and second ends;

a second semi-circular toroidal ferromagnetic piece having first and second ends;

said first and second ends of said first toroidal ferromagnetic piece being arranged to face the first and second ends of said second toroidal ferromagnetic piece, such that the ends of said first and second toroidal pieces are opposed and spaced apart;

permanent magnetic means interposed between said ends of said toroidal ferromagnetic pieces and integrally joined with said toroidal ferromagnetic pieces;

coil means surrounding a portion of said first toroidal piece or said second toroidal piece, said first and second pieces and said permanent magnetic means defining a closed toroidal structure.

8. The toroidal inductor device as defined in claim 7, wherein said magnetic means comprises two spaced-apart permanent magnets.

9. The toroidal inductor device as defined in claim 8, wherein said spaced-apart magnets are arranged along a single plane.

10. The toroidal inductor device as defined in claim 8, wherein said spaced apart magnets are arranged along parallel planes, and angled to a diametric plane of said toroidal inductor device.

11. The toroidal inductor device as defined in claim 8, wherein said spaced apart magnets are arranged along non-parallel planes.

12. The toroidal inductor device as defined in claim 7, wherein said toroidal assembly includes at least one pole piece running along a perimeter of said toroidal structure.

13. The toroidal inductor device as defined in claim 7, wherein said toroidal assembly includes a plurality of pole pieces running along a perimeter of said toroidal structure.

14. The toroidal inductor device as defined in claim 13, wherein said toroidal structure includes an inner perimeter and an outer perimeter and wherein said plurality of pole pieces run along said internal perimeter and said external perimeter.

15. The toroidal inductor device as defined in claim 7, wherein said toroidal structure includes an inner and outer perimeter and said coil means extends along portions of said inner and outer perimeters.

16. A multi-phase assembly, comprising:

a magnetic circuit having a first frame and a second frame, each of said first frame and second frame having a perimeter and at least one leg extending within said perimeter of said frame;

said first and second frame being retained in juxtaposition with permanent magnetic means interposed between said first and second juxtaposed frames;

coil means surrounding at least a portion of said perimeter, and surrounding a portion of said at least one leg;

wherein said first and second frames and permanent magnetic means are arranged to form an integral unit.

17 The multi-phase assembly as defined in claim 16, wherein said magnetic means are contained within a gap between said first and second frames.

18. The multi-phase assembly as defined in claim 16, wherein said magnetic means comprises a plurality of magnets positioned adjacent said perimeter.

19. The multi-phase assembly as defined in claim 18, wherein said magnets are divided into a plurality of sets of magnets, each set of magnets being located adjacent a side of said integral unit.

20. An apparatus for controlling current in a circuit, said circuit including a source of voltage and an electrical device utilizing controlled current, said apparatus comprising:

a first permanent magnetic device having at least two magnets arranged to produce additive magnetic fields and a first polarity;

a second permanent magnetic core device having at least two magnets arranged to produce additive magnetic fields, and a second polarity;

wherein said first permanent magnetic device and said second permanent magnetic device are arranged in series in said circuit so that said first and second polarities are opposing.

21. An improved magnetically biased apparatus comprising:

magnetic means for producing a first field;

coil means for producing a second field;

wherein said first field is biased perpendicular to said second field so as to reduce energy losses and hysteresis losses in said apparatus.

22. An improved magnetically biased apparatus comprising:

magnetic means for producing a first field;

orthogonally arranged coils for producing a second field;

wherein vectored fluxes produced by said orthogonally arranged coils produce a net flux density which exceeds a pre-determined saturation flux density of the magnetic means.